Method and device for detecting a signal having a certain frequency

This invention relates to signal detection or determining whether a signal oscillating at a certain frequency occurs in a certain line connection or not. More particularly, the invention relates to signal detection in an analogue telephone line.

In data transfer technology, there is often a need to detect whether a voltage and/or current signal having a certain frequency occurs in a certain line connection or not. An example of this is a telephone system in which an analogue telephone exchange sends invoicing pulses as short signal pulses having a frequency of 12 kHz or 16 kHz. Another device of the telephone system, such as an OLIC (office line interface circuit), which simulates an analogue telephone,must be able to detect the invoicing pulses correctly, which means that all invoicing pulses must be detected, but other signals must not be allowed to cause a faulty detection.

A conventional method for detecting a signal of a certain frequency is to use two circuit devices 101 and 102 connected in series as in Figure 1, of which devices the first one in relation to the direction in which the signal moves is a passband filter or a corresponding frequency-sensitive circuit device 101, and the second one is a level indicator 102 which is not frequency-sensitive. The filter 101 has a certain frequency response, in which the center frequency of the passband is the same as the desired signal frequency to be detected. The status of the output of the level indicator 102 is active when a signal of a sufficiently high level comes through the filter 101, and otherwise passive. The arrangement shown in Figure 1 entails many drawbacks. It may be laborious to make the frequency response of the filter 101 as desired, and it may require the use of a large and/or complicated filter. It is difficult to move the passband of the passband filter for a remarkable distance, and therefore, if the same device should be used according to selection to detect a signal of either 12 kHz or 16 kHz, it may be necessary to change the filter 101 in connection with the selection.

Patent application FI-944857 discloses a more advanced arrangement as shown in Figure 2 for detecting a signal of a certain frequency. The voltage signal running in the twin cable 201 is amplified in the amplifier 202 and fed via a decoupling capacitor 203 to a demultiplexer 204, which is controlled by a clock signal CLK. The demultiplexer 204 controlled by the clock signal switches the voltage signal received cyclically to only one of the outputs 205 to 208 at a time. The low pass

filters 209 to 212 filter the voltage signal connected to each output substantially as direct voltage. The comparator 213 makes comparisons between the filtered direct voltage signals and gives an output signal det0, if there is a sufficient difference between the outputs of certain filters.

In the solution illustrated in Figure 2 the idea is that when the frequency of the clock signal CLK is exactly four times the frequency of the signal to be detected, the demultiplexer 204 has time to connect the voltage signal once to each output during one cycle of the signal to be detected. The part of the signal to be detected which is connected to a certain output remains unchanged from one cycle to another. Thus the filters 209 to 212 produce direct voltages of different levels according to which part of the waveform of the signal to be detected is connected to which output. The comparator 213 detects that the voltages produced by the filters 209 to 212 differ from each other. If the twin cable 201 does not contain the signal which was to be detected, but it contains a signal of another frequency instead, the part of the waveform of the signal connected to a certain output changes from one cycle to another. Thus a variable voltage signal which does not proceed through the filter is coupled to each filter 209 to 212. The comparator 213 "sees" the outputs of all filters substantially similar, whereby it does not give an output signal.

The arrangement shown in Figure 2 entails the drawback that the signal to be detected has to be led through both a demultiplexer and filters, which may cause a remarkable attenuation of the signal and losses, which cause warming up of the circuit during use. With regard to the operation of the circuit it is important that the frequency responses of filters 209 to 212 are very similar, which requires the use of relatively expensive, tuned filters. In addition, the arrangement is only suitable for detecting voltage signals.

It is an objective of the present invention to provide a method and arrangement for detecting a signal of a certain frequency in which the above described drawbacks of the prior art can be reduced or eliminated.

The objectives of the invention are achieved by connecting the signal to be detected to parallel, energy-storing components, which are synchronized and the outputs of which can be compared in different ways.

The device according to the invention is characterized in that it comprises
- at least three energy-storing components connected in parallel to a line connection.

- switching means for making a connection selectively from each energy-storing component to a certain reference,
- means for controlling the switching means at a predetermined frequency, and
- means for measuring a certain quantity comparable to the energy stored from each energy-storing component.

The invention also relates to a method, which is characterized in that it comprises steps in which
- the signal is led to at least three energy-storing components connected in parallel,
- each energy-storing component is regularly connected to a certain reference, and
- the value of a certain quantity comparable to the energy stored is measured from each energy-storing component.

According to the invention, a signal which may contain a signal to be detected is connected to parallel, energy-storing components, such as capacitances or inductances, the number of which is not limited as such, but is four in the preferred embodiment of the invention. The operation of the energy-storing components is synchronized so that the signal produced in each one of them is deviated by connecting the output for a certain time to a pre-determined deviating standard level. The switching moments when the deviation takes place, change cyclically at a certain frequency from one energy-storing component to another. The deviation frequency is comparable to the frequency of the signal to be detected. If the signal to be detected is present, the deviation causes standard-sized differences between the outputs of certain energy-storing components defined in pairs. The standard-sized differences are detected by the comparators connected to the outputs. The comparators can be connected together in different ways in order to improve the clarity of the detection.

In the solution according to the invention, the signal to be detected does not proceed through the demultiplexer as in the solution described in the application FI-944857, and the invention does not necessarily require the use of filters on the signal path. The frequency to be detected can be easily selected by changing the above mentioned deviation frequency.

In the following, the invention will be described in more detail with reference to the examples of preferred embodiments and the accompanying drawings, in which

Figure 1 shows a prior art detector,

Figure 2 shows another prior art detector,

Figure 3	shows a preferred embodiment of the invention,
Figures 4a and 4b	show certain voltage forms in the embodiment of Figure 3,
Figure 5	shows another preferred embodiment of the invention, and
Figure 6	illustrates a method according to the invention.

Above in connection with the description of the prior art, reference was made to Figures 1 and 2, and in the following description of the invention and its preferred embodiments reference will be made mostly to figures 3 to 6. In the figures, the same reference numbers are used for corresponding parts.

Figure 3 shows a simplified block diagram, in which a preferred embodiment of the invention suitable for the detection of the voltage signal is illustrated. The signal which is examined for the presence of the signal to be detected, is led to a circuit shown in Figure 3 along line 301, and it is branched to parallel capacitances 302 to 305 of the same size. From one side of each capacitance, there is a connection via a block denoted with R and a certain switching arrangement to the reference potential, which in the embodiment shown in the figure is the ground potential. All four switching arrangements are implemented by means of a multiplexer 306, the operation of which is controlled by the clock signals CLK1 and CLK2. The blocks denoted with R can be simply resistances or they can contain more complicated arrangements. However, all R-blocks are substantially similar. From the capacitances 302 and 304 there is also a connection to the comparator 307, and from the capacitances 303 and 305 there is a connection to the comparator 308. The outputs of the comparators 307 and 308 are summed in the adder 309, the output signal of which is the output signal of the whole circuit arrangement.

For the description of the coupling shown in Figure 3, it is at first assumed that the signal coming along the line 301 is a pure sine wave having exactly the frequency which is to be detected. It is also assumed that the signal to be detected is a pure sinusoidal alternating voltage, whereby its time average is the same as the reference potential shown in Figure 3. The capacitances 302 to 305 are dimensioned high enough to allow the voltage signal to be detected pass through them, so that if there were no connection between the capacitances and the reference potential, an identical sinusoidal voltage would be detected at each point A, B, C and D. The operation of the multiplexer 306 is controlled by the clock signal CLK1 and/or CLK2 so that during one cycle of the signal to be detected there is a connection once from each point A, B, C and D through a corresponding R-block to the

reference potential. Figure 4a shows a timing of the operation of the multiplexer 306 by way of example. In this example, the waveform 401 depicts the voltage signal at the frequency to be detected, and the letters A, B, C and D denote the times during which a connection from each point A, B, C and D through a corresponding R-block to the reference potential exists.

It is beneficial to the operation of the invention if the input impedance of the R-blocks is substantially smaller than the input impedance of the comparators 307 and 308. In that case, the above described synchronized coupling causes different amounts of electric energy to be stored in the capacitances 302 to 305 depending on at which moment of the cycle time of the signal to be detected the capacitance is connected via the R-block to the ground potential. From Figure 4a it is seen, for example, that the connection from point A or capacitance 302 through the corresponding R-block to the ground potential exists when the voltage of the signal to be detected is nearly at the highest, and the connection from point C or capacitance 304 through a corresponding R-block to the ground potential exists when the voltage of the signal to be detected is nearly at the lowest. Thus the electric energy stored in the capacitances 302 and 304 is seen in that the potential of point A is continuously by a certain constant higher than the potential of point C. The situation can also be described by saying that the direct voltage component integrated into the capacitance 302 is larger than the corresponding direct voltage component integrated into the capacitance 304.

It is important to note that in the embodiment of Figure 3 the capacitances 302 and 305 do not function as integrators in the sense that they would constitute the time integral of the signal to be detected. The integration mentioned above means that each capacitance stores a certain amount of electromagnetic energy from the signal to be detected, and the amount of the energy depends on at which point of the cycle of the signal to be detected and led to the capacitance the connection to the reference potential is made. In Figure 4b, curve 410 depicts the potential of point A and curve 411 depicts the potential of point C. Thus a sinusoidal voltage signal is detected between points A and C and the ground potential, having the same frequency as the signal to be detected, but the voltage signals detected at different points are deviated in relation to one another by a certain constant voltage difference. By examining Figure 4a it can be concluded that the same phenomenon would occur between points B and D, but weaker, because at the points of time denoted by B and D when the connection between the capacitance 303 or 305 and

the ground potential exists, the absolute value of the signal to be detected is relatively close to zero.

The signals according to Figure 4b can be led to the comparator 307 according to Figure 3, because the output of the comparator only depends on the potential difference between its two inputs and not on the absolute value of the potential of either input. A comparator like this is generally characterized by saying that it is immune to common-mode signals. Thus the output of the comparator 307 is active when the direct voltage components integrated into the capacitances 302 and 304 differ from each other by more than the threshold value set for the comparator 307. In the same way, the output of the comparator 308 is active when the direct voltage components integrated into the capacitances 303 and 305 differ from each other by more than the threshold value set for the comparator 308, which is preferably the same as the threshold value set for the comparator 307. Summing the output signals of the comparators 307 and 308 in the adder 309 causes the output of the whole circuit to be active if the output signal of at least one of the comparators is active. The active and passive mode of a certain signal can be defined suitably in each connection; in digital circuits applying conventional logic the active mode generally corresponds to the bit value "1", which is described by a certain positive voltage, and the passive mode corresponds to the bit value "0", which is described by a voltage close to the ground potential.

It cannot be known in advance how the switching cycle of the multiplexer 306 relates to the phase of the signal to be detected. Figures 4a and 4b relate to a situation in which the direct voltage component integrated into the capacitance 302 is larger than the direct voltage component integrated into the capacitance 304, but a relative transition of half a cycle of the signal to be detected between the signal and the switching cycle of the multiplexer would change the situation exactly the opposite. Because of this, it is advantageous to implement the comparators 307 and 308 as so-called window comparators, which have an active output when the absolute value of the difference between the input signals exceeds a certain threshold value, regardless of which one of the input signals has a higher value.

For understanding the frequency sensitivity of the arrangement according to Figure 3 it will now be studied what will happen if the signal coming along the line 301 does not contain a signal component at the frequency to be detected. To make it simple it can be assumed at first that the signal coming along line 301 is pure sine wave at a frequency other than the one to be detected. If this other frequency differs only a little from the frequency to be detected, the comparator 307 (likewise 308)

detects a sinusoidal voltage difference between its inputs, the frequency of which is the same as the absolute value of the difference between the frequency to be detected and the frequency of the signal coming along the line 301. The amplitude of the voltage difference depends on the dimensioning of the capacitances 302 to 305 and the R-blocks, or more exactly, the time constant determined on the basis of the dimensioning, which regulates the integration of the direct voltage component into the capacitances 302 to 305. The threshold value set for the comparators 307 and 308 determines how close to the frequency to be detected the frequency of the signal coming along the line 301 must be for at least one of the comparators to give an active output signal.

If the frequency of the signal coming along the line 301 differs substantially from the frequency to be detected, the switching cycle of the multiplexer 306 is spurious in relation to the signal, or the moments at which the connection from each capacitance to the reference potential exists do not occur with any regularity in relation to the waveform of the signal coming along the line 301. Thus only an insignificantly small direct voltage component is integrated into each capacitance 302 - 305, and the output of neither of the comparators 307 and 308 is active.

Figure 5 depicts an alternative embodiment of the invention, in which the energy-storing components 501 - 504 are inductances, in which the electric energy is stored as current and not as voltage. Thus the reference potential (ground potential in Figure 3) must be replaced by a constant current generator 505. Figure 5 also shows the low pass filters 506 - 509 between the energy-storing components 501 - 504 and the comparators 307 and 308. Filters can be used to improve the operation of a device according to the invention especially when the comparators 307 and 308 are not sufficiently immune to common-mode signals. Corresponding filters could also be used in the solution shown in Figure 3.

The embodiments of the invention described above should naturally only be seen as examples, and they do not have a limiting effect on the invention. It should be especially noted that the invention does not require that the switches which in Figures 3 and 5 are switched to the conductive mode with a common multiplexer 306 would be switched in a way that only one switch at a time conducts. In other words, the connection time of one switch can also be shorter or longer than one Nth part of the cycle time of the signal to be detected, where N is the number of energy-storing components (in Figures 3 and 5 the value of N is four); thus it is possible that several switches at a time conduct or that there are moments when none of the switches conduct. The voltage or current signals produced by the energy-storing

components can be combined in many ways before they are led to the comparators, by using a so-called resistance matrix, for example. The number of parallel, energy-storing components is at least three, in which case at least three comparators are needed to compare the voltage or current differences of all the three possible pairs.

The frequency of the clock signals used to control the multiplexer should be programmable, whereby the device can be applied to detect a signal of almost any frequency by changing the frequency of the clock signal only. The aliasing phenomenon, known from sampling theory, means that a certain sampling frequency (a certain clock frequency in the present invention) causes the detection of both the signal which was to be detected and its harmonic frequencies. If the harmonic frequencies are harmful, the device according to the invention can be equipped with an anti-alias filter in a manner known as such from sampling theory. On the other hand, some applications may even benefit from the fact that the same device can detect both a certain basic frequency and its harmonic multiples.

The threshold values used by the comparators can also be made programmable. Furthermore, it is possible to present a modified embodiment in which the output signal of the whole device is led in a known manner as feedback to influence the values of the threshold signals used by comparators, whereby the hysteresis phenomenon can be utilized in the operation of the device.

The device according to the invention can be manufactured from cheap, ordinary separate components or it can be implemented as part of an integrated circuit or as an integrated circuit on its own.

Figure 6 shows the method according to the invention as a flowchart. Step 601, setting the clock frequency, can be carried out always when there is a need to set a new signal frequency to be detected; otherwise step 601 can be ignored. In step 602 the signal is led to parallel capacitances or other energy-storing components, in step 603 connections are made in turns from parallel capacitances or the like to the reference potential or current, and in step 604 the voltage or current differences are measured, which may include filtering and combining. In step 605 it is determined whether a difference which is larger than the set threshold value has been found in the measurement. Depending on the result, return to the start takes place through step 606 or 607. If hysteresis is used to regulate the threshold values used by the comparators, a certain feedback from steps 606 and 607 to step 605 is also added to the flowchart.